The importance of coccidioidomycosis as an occupational disease has increased in the southwestern United States. This report discusses the aspects of the disease in terms of its geography, the agent, occupation, dust conditions, and various other factors. A control program is outlined.

EXPOSURE FACTORS IN OCCUPATIONAL COCCIDIOIDOMYCOSIS

Lawrence L. Schmelzer, M.P.H., and Irving R. Tabershaw, M.D., F.A.P.H.A.

THE rapid and increasing influx of industry and agriculture into the southwestern United States has heightened the importance of coccidioidomycosis as an occupational disease. Before 1938, this disease was of little interest because relatively few clinical cases were recognized and the morbidity caused by primary infection was not appreciated. In that year, Dickson and Gifford,[1] reporting on several years of study, clearly established that the benign, primary form of the disease was an important cause of illness in the endemic areas, and that the disease is caused by inhalation of spores of Coccidioides immitis. During World War II, coccidioidomycosis was shown to be the cause of significant illness among soldiers in training at camps in the endemic areas. Studies by Smith, et al.,[2] showed that preventive measures, notably dust control, were effective in reducing the rate of infection and the seriousness of epidemics.

Epidemics have also been reported in susceptible groups of university personnel that entered endemic areas. In 1942, Davis, et al.,[3] reported infection in seven of 14 students and staff from Stanford University who made a field trip to the San Joaquin Valley. In 1954, four students from the University of California at Los Angeles contracted the disease in similar circumstances, and one student, not participating in the field trip, developed disease through the handling of contaminated specimens in the laboratory.[4] In 1962, 100 per cent infection was reported in a group of 16 persons from UCLA who participated in an archaeological field study near Los Banos, Calif.[4] Again in 1965 three students from UC Berkeley developed clinical disease after a field trip in the same general area.

Coccidioidomycosis ranks high among the infectious occupational diseases[5] as shown in Table 1. Further, the case fatality rate closely parallels that of tuberculosis as shown in Table 2.[6] These rates are based on reported clinically recognized cases. In both diseases, primary infection usually goes unnoticed. Fatality rates for both diseases are considerably less when based on total number of infections.

In spite of the fact that coccidioidomycosis is in most instances inapparent or mild, the disease causes significant dis-

Table 1—Number of disability cases of selected occupational diseases in California by fiscal year of report*

Disease	Number of disability cases			
	1962-1963	1963-1964	1964-1965	3-year total
Coccidioidomycosis	21	34	27	82
Tuberculosis	28	29	24	81
Anthrax, brucellosis, Q fever	11	13	13	37
Psittacosis	1	1	1	3
Tetanus	1	2	1	4

* From: Work Injuries in California, Quarterly Statistical Summary. State of California Department of Industrial Welfare, Division of Labor Statistics and Research.

ability in California workers. Although the 106 cases reported in six years[7] may not appear an unduly large number, the degree of disability in these cases is noteworthy (Table 3).

A large proportion required hospitalization and absence from work lasting weeks or months was not unusual. As late as 1957, coccidioidomycosis caused more disability at Williams Air Force Base in Arizona than any other disease including the upper respiratory infections.[8] While the average incidence of both infections was the same, the average disability of 34.6 days caused by coccidioidomycosis was seven times higher than that caused by upper respiratory infections.

Since it is not now possible to provide artificial immunity to those entering an endemic area and since susceptibility to coccidioidomycosis is essentially universal, the introduction of industrial or agricultural workers into endemic areas carries with it the responsibility of assessing the hazard of the disease to such populations. None of the exposure factors in the production of coccidioidomycosis is susceptible to control to the degree necessary to prevent infection entirely. Sufficient knowledge of the direct and predisposing causes of the disease, however, does exist so that it may be possible to reduce both the incidence of infection and its severity.

Geography

Coccidioides immitis has been reported only in the arid and semiarid regions of southwestern United States, in Mexico, Central America, Venezuela, and in the Chaco region of Argentina. The areas of endemicity roughly parallel the boundaries of the lower Sonoran Life Zone, which is characterized by scant rainfall, hot dry summers, alkaline soil, mild winters, sparce flora and fauna and, until recently, few human inhabitants (Figure 1).[9] The creosote bush, Larrea tridentata, is often considered a specific indicator of this life zone.

Evaluation of geography and ecology as exposure factors is complicated by the fact that areas within the lower Sonoran Life Zone may be free of C. immitis, and conversely small endemic areas may occur outside the zone. However, the potential of serious sequelae to infection is sufficient justification to consider any entry into suspected endemic areas as leading to exposure to the disease.

Infectious Agent

Spores of C. immitis are found in the first few inches of the soil and in larger numbers in the vicinity of rodent bur-

Table 2—Case fatality rates for coccidioidomycosis and tuberculosis in California 1960-1963*

	Case fatality rates†			
	1960	1961	1962	1963
Coccidioidomycosis	8.6	12.8	12.3	11.1
Tuberculosis	15.7	12.7	13.1	12.1

* From: California Public Health Statistical Report 1963, Part II Communicable Diseases. California State Department of Public Health.
† Case fatality rates are per 100 cases reported.

Table 3—Number of cases of occupational coccidioidomycosis reported in California during the period January, 1959, to March, 1965, by industry*

Industry		Cases reported
Agriculture		32
Animal husbandry	16	
Field crops	11	
Gardening	3	
Other	2	
Construction		39
Equipment operator	19	
Truck driver-mechanic	6	
Building trades	14	
Professional		22
Engineer	9	
Scientist	8	
Geologist	5	
Other and unknown		13
Total		106

* From: Summary of Reports of Occupationally Contracted Coccidioidomycosis 1959-1965. California State Department of Public Health, Bureau of Occupational Health.

rows.[10] These spores produce mycelial growth during the winter rains and, as the soil dries in the spring, arthrospores are again produced. Tests have shown that the concentration of arthrospores in the soil is highest at the end of the wet season and becomes lower as the dry season progresses. Season and rainfall patterns must therefore be considered in the evaluation of exposure potential for persons entering endemic zones. Importance of this has been shown by Smith, et al.,[2] in the San Joaquin Valley, and by Hugenholtz in a study of 13 years' experience at Williams Air Force Base in Arizona.[11] The average number of infections of base personnel was found to decrease during rainy months and to increase during the dry periods.

The highly infectious nature of C. immitis is illustrated by the fact that from seven to 15 arthrospores insufflated intranasally into mice causes infection and dissemination to the liver and spleen in 35 per cent to 40 per cent of susceptible

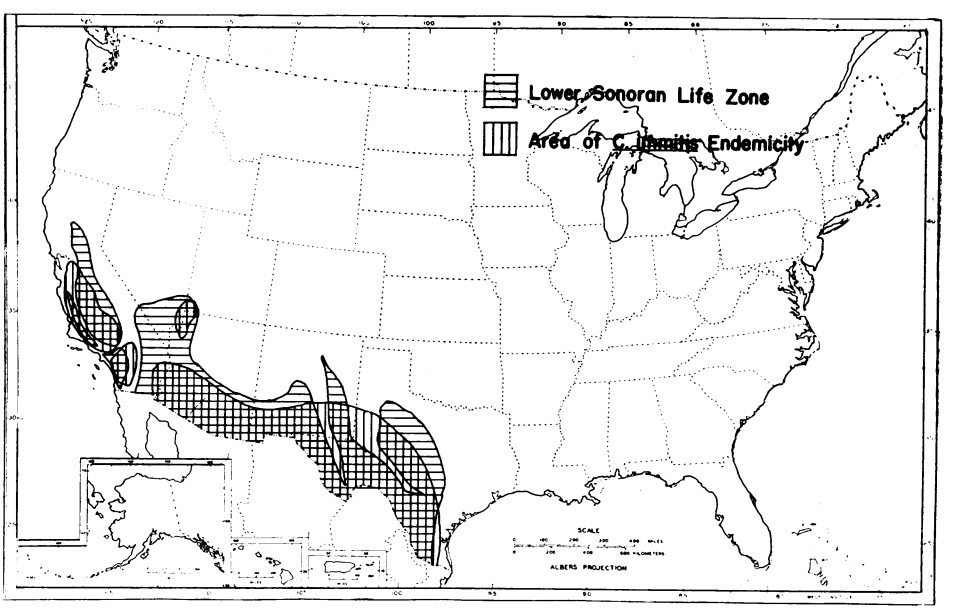

Figure 1—Lower Sonoran Life Zone and area of Coccidioides immitis endemicity in the United States [After Smith, C. E.[9]]

animals.[12] The organism has very simple nutritional requirements for growth, grows on practically any medium, and has been shown to prefer a saline environment[13] including body fluids.

Physical Properties

Typical mature hyphae of C. immitis yield barrel-shaped arthrospores, approximately 2.5 microns in diameter and 4 microns long, alternating with smaller sterile cells. The empty cells rupture easily to free the spores, leaving on the latter cell wall fragments which add to the length of the spore and also decrease the apparent specific gravity. Particle dynamics help to explain the highly infectious nature of the C. immitis and its wide distribution by winds. The important factors are terminal settling velocity and impingement forces, both of which are proportional to the particle size and specific gravity. Although actual spore dimensions vary and the specific gravity is not accurately known, it can be postulated that effective spore diameter is about 5 microns and its specific gravity is about 0.75. Terminal settling velocity for the spores is 0.01 centimeters per second when computed on the basis of these figures. In comparison, a quartz particle having this terminal settling velocity would have a diameter of 1.4 microns. From this it is clear that spores of C. immitis are easily air-borne, settle slowly, can penetrate into the smallest bronchioles and alveoli, and that a significant percentage of retention in the lung can be expected.

Dust Conditions

In the heat of early summer, what little ground cover that exists in the endemic areas withers and dies, winds disturb the surface dust and lift the spores into the air. The slow terminal settling velocity permits the spores to become essentially a permanent atmospheric contaminant under turbulent wind conditions. Such conditions are not unusual in arid regions where thermal phenomena generate severe atmospheric disturbances. Very small, intense, local whirlwinds, known as "dust devils," can raise dust containing large numbers of spores if they pass over pockets of high concentration in the soil. Large, rapidly moving air masses are also common, such as the "Santa Ana Winds" which blow from the Mojave Desert south into the San Fernando Valley. These winds will carry spores into nonendemic areas but the concentration will be low because of the nonselective raising of dust. Soil tests, therefore, cannot assure that an area within or close to an endemic zone is free of the organism and surface travel through or near endemic areas has resulted in exposure and infection.

Occupation

Varying racial and sexual susceptibility influences the severity and disability from coccidioidomycosis. However, since it results from inhalation of air-borne arthrospores, occupational factors must be considered in relation to the magnitude of probable dust exposure. It has been shown that a susceptible population entering an endemic area can experience an annual infection rate of about 20 per cent.[2] No overt dust exposure is necessary; infection can result from wind-borne spores traveling long distances in turbulent air conditions. Labor groups where occupation involves close contact with the soil are at greater risk, especially if the work involves dusty digging operations. The period of disability in cases of occupational coccidioidomycosis reported in California is classified by industry in Table 4.[7] The significant differences in the periods of disability can be ascribed to the variations in exposure resulting from occupation.

Agricultural workers suffered less dis-

ability because their exposure is probably to a few spores at a time. In field crop operations, burrowing rodents are not tolerated and the focus of endemicity associated with them is not present. Tilling of the soil will tend to disperse pockets of high spore concentration so that the dust raised can be expected to contain a relatively low concentration of spores. Similarly, a sheepherder would not be expected to receive a heavy, concentrated dose of arthrospores. This would tend to produce milder disease and a large proportion of inapparent and mild infections.

In the construction trades, exposures may be very different depending on the specific operations. Pipeline, highway, and utility construction often involves work in remote areas where the soil has not been disturbed and where foci of endemicity are usual. When these foci are disturbed, the dust raised can have a high concentration of spores. Digging of foundation and pipe trenches in residential or commercial buildings can lead to similar massive exposure. Similarly, engineers involved in highway or other heavy construction may be subjected to heavy doses if they are working with the construction crews, but may suffer exposure comparable to an agricultural worker if they are only surveying.

The exposures of professionals are highly variable and difficult to predict. Groups of paleontologists and archaeologists have suffered 100 per cent infection when their pursuits led them to dig in or around rodent burrows. Other groups digging in endemic areas have completely escaped infection.

Discussion

Prevention of coccidioidomycosis is complicated by the fact that the organism is a natural and persistent inhabitant of the environment. Determination of concentration of spores in specific locations is not feasible because the selection of appropriate sampling sites and identification of C. immitis is difficult and time-consuming. Furthermore, as previously mentioned, spores can be air-borne for long periods of time and travel great distances. Consequently, the importation of any susceptible labor force into endemic areas carries with it the responsibility for reducing the rate and severity of infection through whatever dust control measures are possible and for providing a vigorous program of medical surveillance.

Control of dust for the prevention of coccidioidomycosis is not a simple matter because of the wide variations in exposures. General dust control measures can afford some degree of protection to all persons working and living in an en-

Table 4—Number of disability cases of occupational coccidioidomycosis in California by length of disability and industry for the period January, 1959, to June, 1962

Industry	Period of disability in days					Total
	0	1–14	15–29	30–50	>60	
Agriculture	6	0	4	4	4	18
Construction	2	1	0	5	13	21
Professions	5	1	2	6	8	22

From: Summary of Reports of Occupationally Contracted Coccidioidomycosis, 1959-1965. California State Department of Public Health, Bureau of Occupational Health.

demic area. As shown by Smith,[2] oiling of parade grounds and barracks areas in military establishments reduced the rate of infection. Similarly, planting of trees and lawns around residences and industrial plants can reduce the rate of infection by about half.[14] Further protection can be provided by filtering and conditioning of air supplied to plants and offices, but this is not complete since it does not control infection resulting from exposure outside the working hours. Protection of agricultural workers and animal husbandmen to any realistic degree is exceedingly difficult. Their exposure to dust is an inseparable part of their employment and working conditions preclude the effective use of respiratory protection.

Operators of heavy earth moving equipment can be effectively protected during working hours by providing air conditioned cabs. This not only protects from coccidioidomycosis but also controls exposure to other dust, noise, and engine exhaust fumes. Efficient and comfortable hoods for individual use are now available with powered blowers for providing filtered air. These are useful on smaller earth moving equipment and for semistationary operations such as oil well drilling. Exposures resulting from manual digging are less easily controlled. Continued use of respirators is very uncomfortable in the usually high ambient temperatures, and workers resist use of this kind of protection. The wearing of respirators can, however, be enforced during recognized periods of high exposure. For instance, building tradesmen should wear respirators when digging foundation excavations or pipeline trenches. Similarly, highway engineers can wear respirators when working around earth moving machinery but could dispense with this when surveying ahead of or behind construction crews. Scientists should be protected during actual digging operations but not necessarily during exploration.

Skin testing for previous infection by C. immitis is easy to perform and defines the immune population. All persons hired for work in endemic areas (or whose assignments take them there) should be tested. Assigning immune workers to operations involving known heavy exposures can effectively reduce the incidence of infection. Hiring lifelong residents of the endemic areas can also reduce the incidence of infection since the level of immunity in these people can be expected to be high. This should not, however, be substituted for a program of skin testing and medical surveillance. Negroes and Filipinos have been shown to be more susceptible to developing the highly fatal disseminating form of the disease.[15] Unless such individuals are shown to have developed immunity, they should whenever possible be assigned to work in areas or at jobs where exposure to high concentrations of spores will be minimal.

Periodic medical examinations or interviews are useful to discover a history of low grade or subclinical infection and to evaluate the level of health of the individual. This examination must include repeated skin testing of susceptibles until the patient shows conversion to a positive reaction signifying immunity. Such an individual can then be dropped from medical surveillance for coccidioidomycosis. The medical management of any respiratory ailment suffered by persons at risk who are not immune to coccidioidomycosis should include a skin test.

Research is presently being pursued to develop an effective antigen for producing artificial active immunity to coccidioidomycosis. If successful, this vaccine will make possible the total protection of populations entering endemic areas. However, since man is not the reservoir of the disease, but only an accidental host, eradication will not be possible. Consequently the efforts to prevent disability from coccidioidomycosis must be continued so long as susceptible populations enter endemic areas.

Control Program

A program for limiting the incidence of occupational coccidioidomycosis and reducing the severity of disease in those who become infected would entail the following:

1. Determine if the work location is within the endemic area.
2. Hire resident labor whenever available, particularly if dust exposures may be heavy.
3. Establish a medical program including:
   a. Skin tests on all new employees. If positive they can be assigned to any job; if negative, especially Negroes and Filipinos, job exposure must be carefully evaluated. If heavy concentration of dust cannot be avoided, those with negative skin tests should not be employed at that job.
   b. Retest of susceptibles. This should be continued every three to six months until immunity is demonstrated by conversion to a positive reaction.
   c. Prompt treatment of respiratory illness in susceptibles. Coccidioidomycosis is a suspect in such illnesses (and if such is the case early chemotherapy can reduce the severity).
4. Educate the exposed population.
   a. New employees should be informed of the potential of infection and its consequences.
   b. All employees should be advised to seek prompt medical treatment for any respiratory illness and to inform the attending physician of their possible exposure to the fungus, particularly if the physician practices outside the endemic area.
5. Control dust exposure by:
   a. Oiling or planting of areas around plants, offices, and residences.
   b. Filtering and conditioning of air supplies to plants and offices; providing air conditioned cabs on heavy equipment.
   c. Providing respirators, air supplied helmets, and the like, as indicated.
   d. Preventing transport of C. immitis outside endemic area by thoroughly cleaning equipment and specimens before shipment to other work locations.

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Mr. Schmelzer is environmental health and safety officer, and Dr. Tabershaw is professor of occupational medicine and head, Environmental Health and Safety, Office of Environmental Health, University of California, Berkeley, Calif.

This paper was presented before the Occupational Health Section of the American Public Health Association at the Ninety-Fourth Annual Meeting in San Francisco, Calif., October 31, 1966.